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Investigation of Optical Impacts on Virtualization using SDN-enabled Transceiver and Optical Monitoring

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Abstract: We propose a scheme to introduce real-time optical layer monitoring into optical network virtualization enabled by software defined networking. The optical layer factors that impact the virtualization are characterised and investigated using this scheme experimentally.

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1. Introduction

Optical network virtualization [1] using virtualize-able optical transceiver (V-BVT) and network monitoring have been proposed and demonstrated in [2]. V-BVT [3] introduces the physical transceiver as an abstracted object to the control plane, enabling the on-demand creation of virtual transceivers. Optical network monitoring can obtain real-time characteristics and impairments of optical transport layer. Since virtual optical networks (VONs) are co-existed while isolated on the shared underlying optical network substrate, any variations in substrate will affect the performance of VONs in supporting their accommodated services. To take full advantage of real-time monitoring, variations in optical network substrate should be especially characterized, and considered as supplemented factors into the optimization strategy when virtualizing V-BVT resources to support VON creation.

VON consists of virtual links interconnected by virtual nodes. For accommodating a service with a given QoS, (re-)establishing of virtual links is determined by a virtualization strategy. The general strategy considers the status of network links obtained by optical link monitoring in order to make a decision that can meet both QoT and QoS. However, status of V-BVT resources also impact such decision making, since V-BVT creates virtual transceivers that actually generate/terminate these virtual links. For example, to determine a modulation for each virtual link will not only depend on status of network links but also on the extinction ratio of V-BVT subcarriers. Moreover, performance at the receiver on a virtual path can also influence the decision making. Since a perfect matching filter is not always achieved for every virtual link, it creates a time-varying OSNR penalty that can exceed the system margin and cannot be predicted by optical link monitoring. This will degrade the QoT of the virtual link and thus the VON performance, while monitoring the performance at the receiver can capture such degradation. Furthermore, V-BVT (re-)configuration duration is also important, either when recovering virtual links from the failed ones or switching from one modulation to another, as it will affect the QoS of a given service and should be studied.

In this paper, we propose a scheme to include optical layer monitoring into optical network virtualization. A V-BVT virtualization strategy will obtain the monitored data in this scheme, and enable them as supplemented inputs in creating virtual transceivers. We then employ this scheme on an experimentally to investigate the impact of these factors, which are status of V-BVT resources, performance at receiver and V-BVT (re-)configuration duration.

2. Software defined networking and monitoring enabled virtualization scheme

The scheme proposed in Fig.1 contains optical layer devices, control plane and a V-BVT virtualization strategy. Using OpenFlow extension, V-BVT and switches are managed by the control plane (e.g., OpenDaylight (ODL) controller) and the application runs upon it. The monitoring function is performed using wave analysers (WA) and receiver, and a database is updated by them. To monitor optical links at a switching node, the WA is enabled by controller to switch among node output ports to monitor multiple links. Status of optical links can be obtained, including in-band channel OSNR and utilization per link. To monitor status of V-BVT resources, WA can switch among node input ports to obtain status of subcarriers pool in multiple V-BVTs, e.g., extinction ratio of subcarriers. Performance at the receiver can be directly updated to the database using optical modulation analyser (OMA), including receiver OSNR and BER. V-BVT re-configuration duration is obtained and pre-stored in the database. V-BVT virtualization strategy fetches up-to-date information from the database and runs the optimization algorithm. Strategy in Fig. 2 covers the conditions for optimizing the VON accommodation based on the given network and hardware resources. The decision making includes physical links that accommodate virtual links, virtual link central frequency, modulation baud rate and format that decide the link width, etc. When a variation is detected by monitoring that affects V-BVT resources in creating virtual transceivers, reconfiguration is triggered. The three factors we investigated are added as supplements into the inputs of the strategy (right hand side) to facilitate the decision making of virtualization strategy to enhance VON performance. Considering the status of V-BVT

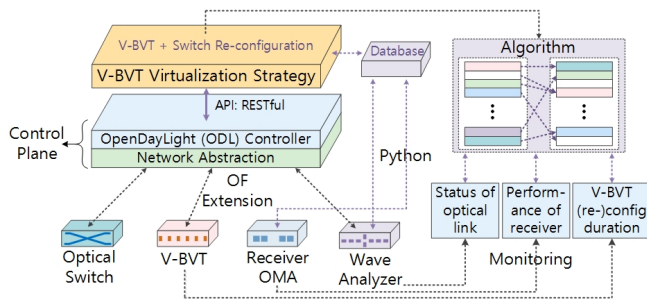


Fig. 1 Monitoring scheme of optical and Ethernet layer in combine with SDN

subcarriers pool, subcarriers having a better extinction ratio will be preferable for application of higher-level/higher baud rate modulation format, or physical links require stringent QoT. Complement to link monitoring, if the receiver OSNR and BER are lower than the threshold, switching of the modulation format or path will be triggered even if the link OSNR is still tolerable. For services with a stringent QoS, if the V-BVT re-configuration duration is intolerable for recovery, other solutions have to be considered before resource planning, e.g., a backup solution.

3. Experimental and Results

The experimental platform shown in Fig. 3 is applied to analyse the factors stated that affects the virtual transceiver creation in supporting VONs. A similar set-up in [2] is used to demonstrate monitoring in optical and Ethernet layers. In Fig. 3, subset (a) is a V-BVT implementation that contains a subcarriers pool and modulators pool; optical fibre switch is in subset (b) as experimental network topology and is monitored by WA; adaptive filter and coherent receiver are also implemented in subset (c) using a wavelength selective switch (WSS-3) and OMA, where each channel is filtered before being detected, processed and analysed offline. These components are all controlled by ODL enabled SDN control plane using OF extension shown in subset (d), where a database is also developed. WA and OMA both update the database with monitored real-time status of network links and performance at receiver through an interface written in Python. V-BVT virtualization strategy runs upon the control plan, fetching monitored data from database to optimize V-BVT hardware resource in creating virtual transceivers.

In Fig. 3 (a), subcarriers pool in V-BVT is achieved by a simple and cost efficient externally injected gain switched laser [5] with a tunable free spectral range (FSR). It generates a group (~ 20) of intrinsically spectrally locked multi-wavelength subcarriers (100 kHz linewidth) when the FSR is adjusted to 17.5 GHz to fit into the minimum filtering width of WSS (12.5 GHz) as shown in Fig. 3 (e). Fig. 3 (g) characterises the status of V-BVT subcarriers, which is extinction ratio and flatness of the comb tones. 14 of them are selected to compose a V-BVT subcarriers pool as framed in Fig. (e) before sent to the input of WSS-1. Tone 1, 2, 13 and 14 has a lower extinction ratio which needs to be considered when applying modulation on them. The modulators pool is pre-connected to the outputs of WSS-1 and contains formats of 40 GBd BPSK, 28 GBd DP-QPSK and 26 GBd 16QAM. Different virtual transceivers are created through the selection of subcarriers in combine with modulation formats. The spectra of these virtual transceivers are sent into network topology implemented by a SDN enabled fibre switch in Fig. 3 (b).

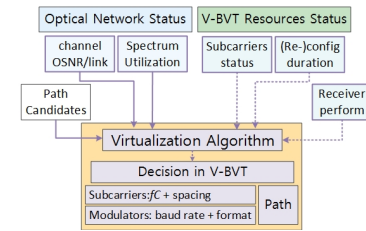


Fig. 2 Monitored optical layer information as inputs of V-BVT virtualization. The investigated factors (on the right) are added as supplemented inputs that impacts optimization of V-BVT virtualization

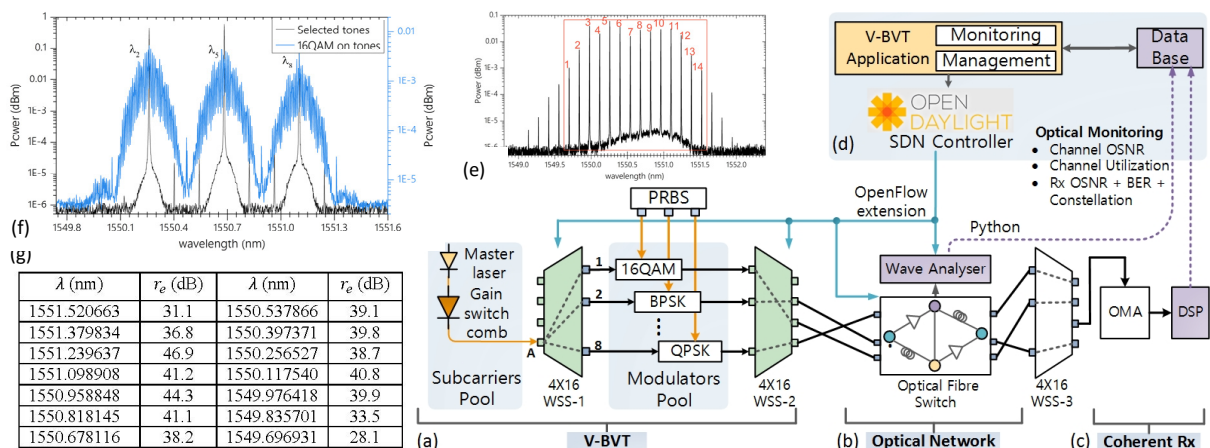


Fig. 3 Experimental implementations: (a) V-BVT platform, (b) arbitrary topology configuration and network status monitoring, (c) receiver side monitoring, (d) ODL enabled control plane with management application, (e) subcarriers pool of V-BVT and its selection, (f) spectrum of created virtual transceiver after selecting subcarriers central frequency and modulation format, (g) table of extinction ratio detected for each subcarrier

By configuring ports of the fibre switch in the controller, status of optical links (10% power) at any node in this topology can be obtained by WA in a resolution of 150 MHz, including channel OSNR and utilization per link.

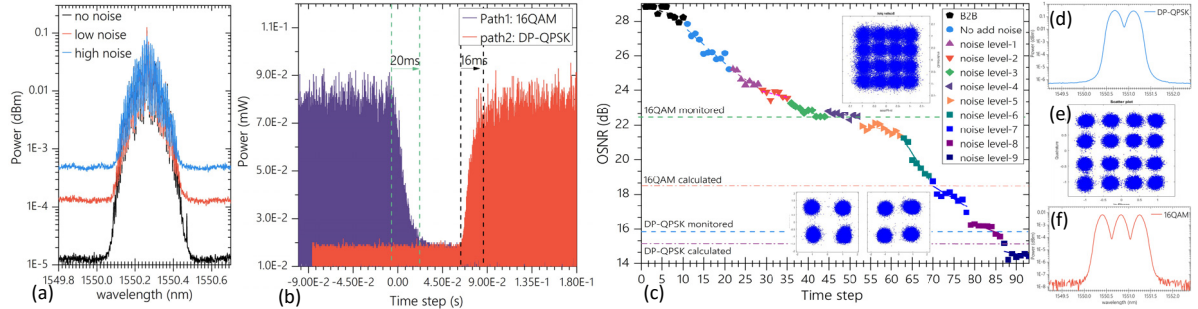


Fig. 4 Monitoring results obtained in optical layer: (a) spectrum of monitored 16QAM channel on tone x degradation at different noise stages, (b) obtained switching time between selection of different path and modulation formats, (c) real-time link OSNR degradation in compare with theoretical threshold and modulation re-selection, (d) initial spectrum using 16QAM on tone xx, (e) initial constellation before link noise accumulated, (f) spectrum after re-selection of subcarriers and modulation formats of V-BVT

In the virtualization strategy, for each service, subcarriers and modulation formats from V-BVT are determined by evaluating the status of V-BVT subcarriers and optical links described above. To consider status of V-BVT subcarriers, referring Fig. 3 (g) as an example, subcarriers have a higher extinction ratio (e.g., tone 3 in 1551.24nm with 46.9 dB, tone 5 in 1550.96nm with 44.3 dB and tone 8 in 1550.538nm with 39.1 dB) are preferable for a higher data rate service (e.g., 100 Gb/s) and a higher-level modulation formats (16QAM). The ones have lower extinction ratio are assigned to BPSK (e.g., tone 1 with 28.1dB, 2 with 33.5 dB, and 14 with 33.1 dB) and the remaining are modulated by DP-QPSK. This strategy considers the deficiency at transmitter side to ease the transmission and receiving pressure. Fig. 3 (f) represents the spectra of the created virtual transceivers that are modulated by 16QAM on good tones 3, 5 and 8 after WSS-1 at output 1. To consider the status of optical links, real-time channel utilization on these links is firstly fetched from the database. The strategy determines a 100km path from the topology by considering the available contiguous spectrum on the link combine with with wavelengths of the selected tones. After sending the 16QAM spectrum on this path, real-time link OSNR is then obtained by monitoring these three channels. Fig. 4 (a) indicates the degradation of channel 8 under increased noise that is randomly coupled into the link through a fibre switch to emulate link failure. This procedure is detailed in Fig. 3 (c) to analyse the relation between the monitored link OSNR and performance at the receiver. Theoretical OSNR thresholds of 26 GBd single-pol 16QAM and 28 GBd DP-QPSK are shown plot, which are calculated as 18.352 and 15.347 dB considering the matching filtering. 16QAM with no link noise is detected in Fig. 4 (e). When the link OSNR drops to ~22.5 dB with the increase of noise, the receiver indicates a BER higher than 10^{-3} though link OSNR is still 4dB higher than theoretical value. Such degradation will trigger the strategy to determine another modulation format can be used on the same link. DP-QPSK modulation format is then reconfigured to continue the service. If link OSNR keeps dropping to 16 dB (0.8 dB higher than theoretical value), the receiver fails to detect DP-QPSK. This triggers the strategy to determine other paths instead. Fig. 4 (d) indicates the 2-channel DP-QPSK on a new path recovered from a 3 channel 16QAM in Fig. 4. (f). V-BVT (re-)configuration duration between two paths is also observed in Fig. 4 (b), while path-1 is modulated using tone 5 with 44.3 dB extinction ratio by 16QAM takes around 20ms to switch off the channel. Meanwhile, path-2 is switched on instead using tone 7 with 38.2dB extinction ratio by DP-QPSK and takes around 16ms to switch on.

4. Conclusion

We have experimentally investigated three optical layer factors that impact virtualization using optical monitoring techniques in an SDN enabled environment. The status of V-BVT resources, performance at the receiver and V-BVT (re-)configuration duration all affect the virtualization strategy and should be added as supplemented input into the strategy to facilitate optical network virtualization through virtual transceivers created by V-BVT.

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